Valero Energy Corporation's Paulsboro Refinery and Bently Nevada's growing partnership

A refinery explores new approaches to machinery management and skills enhancement

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Valero's Paulsboro, New Jersey, refinery began operation during the early 1900s and remains a significant producer of petroleum products today. The facility was acquired by Valero in 1998, adding significantly to Valero's total capacity. Throughout the years, refinery units have been upgraded and new units built to keep pace with increased production demands and new opportunities. However, with the refinery's aging machinery population, it had become a challenge for Valero to maintain the refinery's 1,100 pumps at acceptable reliability levels.

The goal: increasing MTBR for reduced maintenance costs

In 1996, prior to the purchase by Valero, the plant's Reliability Group determined that:

- 67% of the overall Machinery budget was being spent on the recurring maintenance of sealed pumps.
- Seal problems were the largest factor reducing reliability.
- The Mean Time Between Repair (MTBR) was approximately 25 months for the sealed pump population.

More importantly, it was recognized that if MTBR could be doubled, maintenance expenses *would be cut in half*. An intensive seal management program was then initiated by partnering with a seal vendor. This program also included classroom training for machinists, operations personnel and supervisors, and engineers. Initial MTBR gains were quickly realized, although by the 2nd quarter of 1997, after less than two years, the MTBR trend had stalled at 38 months.

To increase the MTBR, it was realized that it was necessary to improve the skills of the vibration monitoring

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personnel. Although monthly data was acquired in the plant, sufficient knowledge to analyze and manage that data did not exist. Many problems were only addressed when vibration became severe, or when something unusual was noted, and subtle pre-failure characteristics were often overlooked. Coupled with a lack of confidence in spare equipment reliability, this often forced Maintenance to operate in a "reactive" mode. This work mode, "putting out the fires," prevented the planning and time investment required to properly address equipment problems before they turned into catastrophic failures and to do excellent work.

Valero recognized that changing their

vibration monitoring program and their culture was necessary. Several "typical" options were considered, such as hiring a full time specialist, formal training, etc. Valero ultimately decided to hire a knowledgeable contractor to train their people in key areas, thus strengthening the organization, while providing interim technical analysis, support, and program management.

Valero had previously worked with Bently Nevada's Machinery Management Services (MMS) engineers to solve machinery problems. This gave them insight into MMS' abilities during projects involving their "critical" machinery, such as jet-pumps, centrifugal compressors and gas turbines. Bently Nevada's Product Service group had also been previously used to maintain the plant's various monitoring and protection systems. Based on this history, Valero was comfortable working with Bently Nevada to help define the new program.

The proposal: a machinery management program

After performing a needs analysis in late 1997, including review of the vibration monitoring program, machinery failure and repair data, and discussions with various personnel, Bently Nevada proposed a machinery management program with several key areas of focus:

- Train the machinists who were assigned to the Reliability department in vibration data acquisition and analysis.
- Expand and improve the refinery machinists' use of laser alignment instrumentation.
- Eliminate some pumps from the "Bad Actors" list.
- Optimize and perform training on the Data Manager® 2000 and Trendmaster® 2000 systems.
- Optimize usage of the existing portable data collector (PDC) system (see sidebar).

In May 1998, Valero awarded Bently Nevada the contract, and work began immediately. Due to the program's encompassing nature, it was broken into multiple phases. This provided us with an efficient means of structuring activity, monitoring progress, and assessing results. Review periods were scheduled between phases to determine if modifications were needed, based upon developing business needs, and to plan subsequent phases.

Phase 1, ending in November 1998, had two MMS engineers assigned to the project full time, alternating weeks spent on-site. This provided different viewpoints on refinery issues and complemented the overall strategy. During Phase 2, which lasted from December 1998 through April 1999, MMS engineers were on-site two days per week, as the skills and knowledge of the machinists assigned to Reliability continued to increase. Phase 3, which began in October, will be 2 days per week for 6 months. Emphasis will be placed specifically on increasing the Crude and Coker units' MTBR, and continuing the Reliability machinists' vibration training. By Phase 4, which is planned as a consultancy, the Reliability Group should be self-sufficient.

Vibration training

Prior to and during Phase 1, only one machinist was assigned to Reliability and involved with the PDC program. The high workload of gathering monthly data on 1,100 pumps, coupled with no previous vibration analysis training, did not allow him to thoroughly analyze data, and significant problems were being missed or caught too late. Improving the PDC program through extensive training and added personnel were Valero's top objectives for Phases 1 and 2. A second machinist was assigned to Reliability and added to the PDC program during Phase 1. By dividing data acquisition responsibilities, the two machinists now have enough time to acquire *and* analyze the plant data.

To address the training issue, Bently Nevada's MMS engineers taught a series of diagnostic courses, and used computer-based training (CBTs) coupled with field training. Classroom training was done at Bently Nevada's training center in Media, Pennsylvania, and locally at Valero's on-site training facility. Included were:

- Bently Nevada's CBTs covering various data acquisition topics, such as Measurement Conventions, Noise and Error Sources, Noise Reduction, Phase, Transducer Operation, and Transducer Selection.
- Bently Nevada's Machinery Diagnostics Course, which involves discussion, demonstration, and hands-on analysis of rotating machinery concepts and problems, such as phase angle, steady state and transient vibration data, dynamic stiffness, fundamental synchronous rotor response, mass unbalance, misalignment, rubs, fluid-induced instabilities, and others.
- Data Manager® 2000 (DM2000) and Trendmaster® 2000 (TM2000) online systems training. DM2000 is used to continuously monitor and acquire steady state and startup / shutdown data from nine critical refinery machine trains. TM2000 currently acquires

intermittent steady state data from 45 machines in the Coker unit. These online systems eliminate the need for PDC data acquisition and provide high-density data to detect problems at their early stages.

- Advanced usage of Reliability's portable data collector hardware and software to implement various alarming and diagnostic features and to streamline the analysis process.

On-the-job training was also crucial because it reinforced what was learned during classroom training. To support this, a "Pump of the Week" program was implemented. In this program, Reliability machinists identify one or two pumps each week during data collection that have high vibration levels or unusual characteristics. Appropriate data is plotted and reviewed with MMS engineers to perform a root cause analysis. After identifying the cause(s), work orders are entered to correct the problems. Post-repair data and follow-up verifies the initial analysis and the pump's suitability for service.

Although the training is still underway, Valero is very satisfied with the results to date. The machinists have advanced from having very little analytical ability to the point where they are performing almost 75% of the analyses and recommendations with no input from the MMS engineers. With further training, we hope to turn this into 100%!

Laser alignment

In Phase 1, it became apparent that improving the alignment skills of the refinery's 25 machinists would contribute to increasing MTBR. All machinists were performing reverse dial indicator alignment, which must be performed in a thorough, precise manner to produce excellent results. As mentioned earlier, Maintenance's reactive work mode often caused the machinists to compromise their standards to complete jobs quickly. This compromised alignment on many machines, with detrimental effects on bearing and seal life and overall reliability. Laser alignment spot checks by MMS revealed that most units had misalignment offsets of 2 to 4 mils per inch, with some units exceeding 4 to 5 mils per inch, well above the general "acceptable" alignment of 1 mil per inch (3600 rpm machines). Multiple instances of motor soft foot were also found, with readings of 10 to 15 mils (2 mils is the desired maximum). Soft foot causes stator deformation and preloads the bearings, reducing their life spans. MMS engineers have been using laser instrumentation since the late 1980s (see article on page 70), and have found the repeatability and ease-of-use to greatly facilitate accurate alignment.

Based upon these results, Bently Nevada recommended that Valero adopt laser alignment techniques and instrumentation as their new standard. Valero subsequently purchased additional laser instrumentation to complement their existing equipment, and MMS engineers spent the remainder of Phase 1 training the machinists, both in the classroom and by doing field training. In conjunction with this, and perhaps even more importantly, Valero's management agreed they would be committed to giving machinists the time to do proper alignments and that "excellent" alignment would be the expectation for every job. The laser alignment computer is now used to document all jobs,

Portable Data Collection – our services don't stop with our own equipment

Many of Bently Nevada's customers employ a strategy that combines both online systems and offline (i.e., portable data collection) systems. For those customers that are not using Bently Nevada's offline products, such as our older Snapshot offerings, we can still provide consulting services, as the Valero article demonstrates. In fact, in addition to simply providing consulting services for plant personnel, some customers have actually elected to outsource their entire machinery management program to us, including the management of their existing walk-around program. We're very comfortable providing such services, and numerous global customers have elected to work with us in this way. It allows them to retain their present investment in equipment, even if it isn't Bently Nevada's, while enjoying the results our service organization can provide.

While we do provide excellent products for portable data collection, and we're bolstering them even further with the upcoming release of our snapSHOT™ for Windows® CE and System 1™ products, we want you to know that our services don't stop with our own products. If you're using a competitive data collector product, don't hesitate to contact us if you feel our service organization can provide valuable outsourcing strategies to help you improve the effectiveness of your program.

and this data is placed in the pump's historical file. Equipment that cannot be aligned within "excellent" tolerances (1/2 mil per inch, 3600 rpm) is reviewed for possible piping or structural corrections. As of May 1999, all the machinists are using laser instrumentation. Despite some initial fears, they are very enthusiastic about the equipment's ease-of-use, accuracy and the results of the program in general. Vibration data shows decreasing instances of misalignment, soft foot, and motor vibration at twice line frequency – all attesting to the alignment program's effectiveness.

"Bad Actors"

"Bad Actors" are defined as those pumps or services having unusually high maintenance costs and/or recurring failures. As of mid-1997, the Bad Actor list consisted of 18 pumps (1.6% of the population) that consumed 14% of the Maintenance budget – a serious source of frustration.

To help Valero address this issue, MMS targeted specific machines by performing detailed analysis of vibration, process, and design data. So far, several Bad Actors have been resolved since beginning the program. The key to this process was using two Bently Nevada 208 Data Acquisition Interface Units (DAIUs) to continuously monitor process parameters (pump suction and discharge pressure, temperatures, motor current, etc.) in conjunction with vibration data. Data is sampled once-per-minute for weeks at a time to understand how the machine and process interact. This correlation of continuous process and vibration data has proven essential in the analysis process. Some examples are:

- Every few months, four vertical pumps experienced wear on their mechanical seals, which was shown by high casing vibration amplitudes (exceeding 1 inch per second). This wear eventually destroys the shaft, line bushings, and housings if not detected early enough. Repairs are often labor-intensive, requiring rework of the housings or complete replacement of the pump unit. Material changes had improved seal and bearing life. However, failures were still occurring too frequently. A major root cause was found to be baseplates that were purposely loose to accommodate misalignment between the pumps' discharge flanges and the common discharge header. Installation of flexible expansion joints is pending, which will allow the units to be properly secured to the foundation, significantly increasing their dynamic stiffness and correspondingly reducing vibration. Further equipment modifications may then be required to maximize bushing and seal life.
- An Overflash pump in hot, viscous, vacuum tower service experienced eight failures and repairs in 1998 alone, including two fires. The pump was completely rebuilt several times, but reliability remained very poor. Run times ranging from 1 day to several months were experienced before seal or bearing failures occurred following rebuilds. Extensive data was taken during Phase 2, and we gained a thorough understanding of the factors contributing to this pump's failures. By monitoring suction and discharge pressures, motor amperage, and vibration, we documented multiple instances of operation when the suction strainer became almost completely clogged, evidenced by suction pressures approaching 1 psia. This causes pump cavitation and vibration levels exceeding 1.0 ips, which rapidly damages the bearings and seal. To avoid cavitation, we conveyed to Operations the need to monitor the differential suction strainer pressure gauges and clean the suction strainer when sufficient differential pressure (DP) develops. This procedure and awareness have applicability to eight other pumps in similar service at this refinery, and can be used at other facilities as well. This troubleshooting has led to cost justification for an upgrade of these pumps to American Petroleum Institute (API) 610 standards, as well as better instrumentation to monitor pump suction pressure. Since implementing this procedure following the last rebuild in March 1999, the unit has been operating reliably with no failures.

These examples, and the other Bad Actors that have been addressed, have a fundamental, underlying goal: by identifying the root cause of a problem, we can provide the plant with an action plan and solution to reduce or eliminate the likelihood of future problems.

Online and offline systems

As mentioned earlier, three primary monitoring systems are used in the vibration monitoring program: Data Manager® 2000 and Trendmaster® 2000 (both online systems), and a portable data collector system. These systems provide all the vibration information used by the Reliability machinists to assess machinery condition. To gain the most value from each system, routine maintenance is required. To help Valero with this, Bently Nevada routinely

works with these systems, ensuring that alarm setpoints, sampling parameters, and configurations remain pertinent, and that they are gathering valid data, and are being used to their full capacity.

The PDC system has been the backbone of the program for several years. However, it is manpower-intensive and does introduce a minor safety concern because someone must physically be at and around each and every machine to acquire data. While this type of data acquisition will probably never be eliminated, recent advancements made by Reliability implementing online systems are significantly influencing how data is acquired and analyzed.

DM2000 continuously monitors nine critical refinery machine trains and acquires steady state and startup/shutdown data, with no intervention required. The system uses Bently Nevada permanent monitoring/protection systems at each machine, coupled with a computer located in the Reliability building. The Reliability machinists can then view current trends and steady state data from each machine, as well as any recent startup or shutdown data, from their office and make recommendations as necessary.

TM2000 uses permanently-installed transducers, multi-plexed to a central PC in the Coker control room, to gather steady state data from 45 machines in the Coker complex. Using a network connection, the Reliability machinists can access the system directly from their office, review the data, and make recommendations accordingly. This system, even with its current limited installation, has eliminated one full day of data acquisition per month from the Reliability machinists' PDC schedule, allowing them to spend more time on analysis and less on acquisition. Current plans are to expand this system to include the Crude or Alky complexes in the near future.

Conclusion

The results of our Valero-Bently Nevada partnership have been very positive. Through continued alignment training with the machinists, vibration training with the Reliability machinists and engineers, intensive analysis of "Bad Actor" pumps, and software system management, Valero feels the program has been extremely valuable and is enthusiastic about continuing. Continued commitment to this partnership by both companies is what has made it a success and a model that can be applied at your plant.

ANNOUNCEMENT

Bently Nevada receives Market Engineering Award

International marketing and consulting company, Frost & Sullivan, as part of a recently released 1998 market study, awarded Bently Nevada its 1998 Market Engineering Award. The award is based on Frost & Sullivan's test and measurement's research and consulting work in the industry in 1998. The award recognizes companies that have worked hard to make a positive contribution, and that exhibit world-class leadership in the industry. The study concludes that Bently Nevada's name recognition, quality products, and marketing strategies are unequaled in the industry.